CALiPER

ROUNDTABLE REPORT

April 2010

DOE Solid-State Lighting CALiPER Program

2010 Roundtable

Prepared for the U.S. Department of Energy by
Pacific Northwest National Laboratory

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Alan Tirpak, Optronic Laboratories, Inc.
Fred Welsh, Radcliffe Advisors

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COMMENTS

The Department of Energy is interested in feedback or comments on the materials presented in this workshop report. Please write directly to:

James R. Brodrick, Ph.D.
Lighting R&D Manager
EE-2J/Forrestal Building
U.S. Department of Energy
1000 Independence Avenue SW
Washington, DC 20585-0121

DOE Solid-State Lighting
CALiPER Program

CALiPER
Standards and Testing
2010 Roundtable Proceedings

ML Paget
EE Richman
HE Steward

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Pacific Northwest National Laboratory
Richland, Washington 99352

Building Technologies Program
Energy Efficiency and Renewable Energy
U.S. Department of Energy



DOE Solid-State Lighting CALiPER Program 2010 Roundtable

Introduction

On February 18, 2010, the Department of Energy's Building Technologies Program hosted a Roundtable meeting among standards-setting efforts, lighting testing laboratories, and key stakeholders in the solid-state lighting (SSL) industry. This Roundtable discussion built upon DOE-led sessions on SSL testing standards held in 2006, 2007, and 2009.[1] For the 2010 Roundtable meeting, 40 experts from the lighting industry who are also involved in key related organizations — such as Illuminating Engineering Society of North America (IES), National Institute of Standards and Technology (NIST), National Electrical Manufacturers Association (NEMA), American National Standards Institute (ANSI), Institute of Electrical and Electronic Engineers (IEEE), Pacific Northwest National Laboratory (PNNL) — and independent photometric testing laboratories, SSL manufacturers, and research laboratories gathered in Gaithersburg, Maryland to discuss current issues related to SSL testing and related standards development.

James Brodrick, U.S. Department of Energy (DOE) SSL Portfolio Manager, welcomed the participants and emphasized the importance of this meeting in contributing guidance to a wide array of SSL activities that are helping to bring high-quality, energy-efficient SSL technologies to market. By bringing deep experience and expertise to the table, the CALiPER Roundtable participants help to identify issues, brainstorm options, and propose constructive actions for DOE SSL commercial product testing and other DOE SSL commercialization support activities, the standards communities, and SSL manufacturers. The 2010 CALiPER Roundtable is the fifth gathering hosted by DOE to provide leadership and support to accelerate the LED standards development process.

The Roundtable meetings are targeted working sessions benefiting from expertise contributed by all attendees. Participants divided into three breakout groups tasked to examine issues, brainstorm options, and identify possible solutions to challenges facing SSL product reliability, evolutions and adaptation of the SSL industry, and SSL product quality. The current SSL standards and testing context of the meeting is summarized briefly below, followed by highlights of the working sessions on each topic.

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[1] An initial DOE-hosted SSL Standards Workshop was held in March 2006. A second DOE-hosted workshop was held in October 2006 along with a kick-off workshop for the DOE's commercial product testing program (later named CALiPER). A third DOE-hosted standards workshop and CALiPER Roundtable meeting was held in November 2007, and a fourth Roundtable was held in March 2009. Proceedings from the November 2007 and March 2009 Roundtable meetings are available online: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2007_caliper_Roundtableproceedings.pdf and http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2009_caliper_Roundtableproceedings.pdf.

CALiPER Standards and Testing 2010 Roundtable Context

LED Standards and Test Methods Progress Update

Eric Richman of PNNL summarized the current status of the development of LED standards and test methods, citing an impressive list of efforts that have been completed or initiated since the initial DOE standards workshop on March 6, 2006. Numerous performance standards, test methods, safety standards, and other related standards impacting SSL and LED products are currently under development, including (but not limited to):[2]

- Completed standards and test methods, the first four
  - ANSI C78-377 (chromaticity)
  - IES LM-79 (luminaire photometric testing)
  - IES LM-80 (LED module lumen depreciation testing)
  - IES RP-16 Addendum "a" (LED definitions)

- More recent standards, test methods, and best practice recommendations
  - UL 8750 LED Safety – available for download
  - NEMA LSD 45-2009 Recommendations for Solid-State Lighting Sub-Assembly Interfaces for Luminaires – available for download
  - NEMA LSD-49 Solid State Lighting – Best Practices for Dimming (should be approved February 5, 2010)

- Documents underway and topics under consideration
  - TM-21 – Lifetime extrapolation method (use with LM-80) – statistical model runs to evaluate decay models, "X times test hours" life limit, conservative estimates, need for better data than 6000/1000
  - RP-16 – additional LED definitions (soon to be approved)
  - CIE TC1-69 – Color Quality Scale (new CRI-type metric)
  - NEMA SSL-1 – LED Drivers
  - IES LED Application Guideline
  - C78.377-2008 (color) – currently in comment collection to address points of confusion and differences across markets
  - IEEE P1789 Biological Effects and Health Hazards from Flicker… (in final review)
  - LM-XX1 Methods for the Measurements of High Power LEDs (in draft development)
  - LM-XX2 LED "Light Engine" measurements (PIF for approval)
  - IES LM-79 (luminaire photometric testing) – voltage and power quality concerns
  - IES LM-80 (LED module lumen depreciation testing) – specifics on test parameters, revisit limited 6000 hr/1000 data, exploring accelerated test, urgent need for TM-21
  - ANSLG meeting topics
    - LED package size standardization in support of interconnects – working group formed (R. Weber, T. Stimac)

[2] For more information about SSL standards, visit http://www.ssl.energy.gov/standards.html and download the DOE fact sheet, "LED Measurement Series: solid-state Lighting Standards," http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_standards.pdf.

    - End-of-life indicator
    - Driver reliability

- Other worldwide organizations also working on mostly parallel documents
  - CIE
  - IEC; for example, IEC standards under review by ANSLG WG
    - IEC 62560 ((self-ballasted LED for general lighting (greater than 50 volts); Safety (retrofit))
    - IEC 62612 (LED performance)
    - IEC 62031 (LED module)
    - IEC 62504 (LED definitions)
    - IEC 61345-2-13 (safety specifications for ballasted LED)
  - IEEE

DOE provides both broad-based and specific support to SSL standards efforts. Specific examples of DOE support include the National Voluntary Laboratory Accreditation Program (NVLAP) process workshop on LM-79 and LM-80 accreditation (conducted by NIST on February 16-17, 2010), NIST lamp standard support, uncertainty budget development subcontract (starting shortly), and the NIST LED color human response study (soon to be funded).[3,4] To progress effectively, current standards and new standards rely on champions, drivers, and critical commenters from industry — such as many of the experts that participate in the CALiPER Roundtable meetings.

[3] National Voluntary Laboratory Accreditation Program (NVLAP http://ts.nist.gov/standards/accreditation/index.cfm) recently issued a program-specific update on energy-efficient lighting products including solid-state lighting. This update enables accreditation of laboratories for IES LM-79 and IES LM-80 testing. http://ts.nist.gov/Standards/Accreditation/handbook.cfm.

[4] The published IESNA LM-79-08 testing standard, *IESNA Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products*, covers LED-based SSL products with control electronics and heat sinks incorporated. The published IESNA LM-80-08 testing standard, *Approved Method: Measuring Lumen Maintenance of LED Light Sources*, addresses the measurement of lumen maintenance testing for LED light sources, including LED packages, arrays, and modules only. It does not provide guidance or recommendations regarding prediction estimations or extrapolations for lumen maintenance beyond the limits of the lumen maintenances determined from actual measurements. Available from http://www.ies.org/.

Where CALiPER Is Today

In a little over 3 years, the DOE CALiPER program has tested more than 270 SSL products and many benchmark lamps and luminaires. Mia Paget of PNNL provided a quick synopsis of current CALiPER activities and recent CALiPER results. CALiPER results and expertise also feed into a number of related DOE SSL activities such as support for standards activities, SSL Quality Advocates, SSL Manufacturer Initiative, SSL manufacturing R&D roadmap, GATEWAY demonstration projects, NGLIA Solid-State Lighting Product Quality Initiative, design competitions, and the Technical Information Network.

In 2009, NVLAP initiated the process for laboratory accreditation for both IESNA LM-79 and IESNA LM-80 testing of SSL products. Ultimately, with laboratories that are NVLAP-accredited for photometric testing of SSL products, CALiPER qualification of testing laboratories will no longer be needed. For now, the industry is in an interim period, moving from CALiPER qualification toward NVLAP qualification. To provide assistance during this interim period in 2009, CALiPER continued qualification of a number of independent testing laboratories for LM-79 testing and also provided a mechanism to manufacturer laboratories for interim qualification for LM-79 testing while NVLAP accreditation is in process. The testing communities and lighting industry appear now to understand concepts surrounding LM-79 testing. CALiPER testing is still showing overall steady improvement in photometric performance of SSL products — with an ever-expanding number of new, market-available generations of products in every lighting application area.

Three CALiPER summary reports were issued in 2009 covering Rounds 7, 8, and 9.[5] These rounds of testing included outdoor lighting, downlights, 2'x2' troffers (and 2'x2' flat panel luminaires, 4' linear replacement lamps (tested as bare lamps and in 2'x4' troffers), and a wide array of small replacement lamps such as MR16 lamps, PAR lamps, and small, omni-directional replacement lamps. SSL products are performing quite well as compared to incumbent technologies in some application areas, such as recessed downlights. For other applications, SSL products are not yet achieving the light output and efficacy levels of incumbent technologies, such as 4' SSL linear replacement lamps, which are clearly not yet competitive with T8 linear fluorescent lamps. Upcoming CALiPER testing will focus on parking garage fixtures, cove lighting, and wall packs.

CALiPER continues to perform absolute photometry on SSL and benchmark products, providing detailed reports, general analyses, and benchmark reports to the public. In addition to the basic photometric testing, CALiPER is also contributing to other aspects of SSL product testing, such as product reliability, long-term studies, *in situ* testing, dimming, flicker, glare, and testing uncertainty. A primary purpose of the Roundtable meeting is to identify and prioritize key issues surrounding SSL testing and standards. Taking this objective one step further, the Roundtable also identifies ways in which the DOE and other stakeholder groups may address these issues, through mechanisms such as new standards, related research or testing, and informational or educational support.

[5] Summary reports for Rounds 1-9 of DOE SSL testing are available online at http://www.ssl.energy.gov/caliper.html. Detailed test reports for products tested under the DOE SSL testing program may also be obtained online: http://www1.eere.energy.gov/buildings/ssl/search.html.

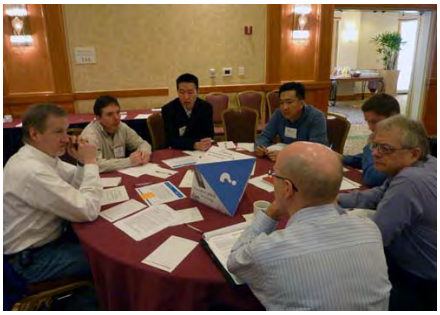
Breakout Sessions: Examining SSL Testing

The CALiPER Roundtable meetings actively engage experts to help guide the CALiPER program and the DOE support of standards activities. Working together in breakout groups, these experts explore an array of current topics surrounding SSL testing to identify and prioritize issues, brainstorm possible solutions, and define actions to be taken by DOE, standards groups, trade groups, and manufacturers to address the issues.

The topics by each breakout group are listed below, along with some of the prompt questions provided to start each discussion. The results of key issues and options discussed in each breakout group are summarized in the next pages and followed by a summary of related suggested action items for each key stakeholder group.

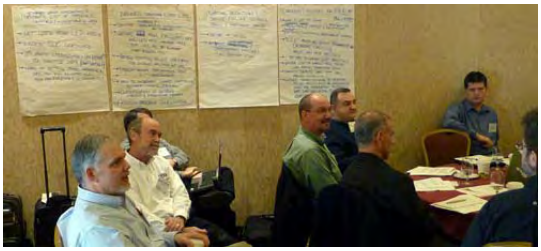
A. SSL Reliability Testing
After brainstorming and identifying several areas of interest, the working group selected the following primary issues to consider:
1. Published list of compatibility of materials for LED applications
2. Drivers – standards and specs
3. Lifetime definition
4. Process and facilities for failure mode analysis
5. Accelerated testing

B. Industry/Market Adaptation
The working group discussed the following key topics:
1. Serviceability and replaceability of lamps and luminaires
2. Education and information for consumer and professional needs
3. Lighting controls – standards and implementation guidance



C. Qualities of (SSL) Lighting
After brainstorming and identifying several areas of interest for consumer or regulatory arenas, the working group considered the following primary issues:
1. Retrofit compatibility (form factor, distribution, and color)
2. Color quality and uniformity
3. Flicker
4. Modularity/interchangeability
5. Power quality/power factor
6. EMI
7. Recyclability/green factor

A. SSL Reliability Testing



- Published list of compatibility of materials for LED applications – This list, with pertinent material details, would be useful for luminaire manufacturers and integrators in developing products. The data would help them to avoid including component or component combinations or interactions that could degrade LED materials and affect output and life.
  - Target group is luminaire manufacturers and other LED chip/module integrators
  - Solicit manufacturers for existing material lists
  - DOE may be best group to coordinate efforts
  - Third party should be used to sanitize/generalize the data (NEMA and/or DOE)
  - Address all relevant materials and not just LED device (include refractors, lenses, etc.)

- Drivers: standards and specs – Standards and performance specifications for LED drivers and their function (dimming) need to be developed and in place for industry use.
  - Define favorable and non-favorable effects including tolerances
  - Gather data from field and industry to support development (test labs, manufactures, etc.)
  - Review existing light source ballast test methods for applicable guidance
  - Develop both driver performance and measurement standards
  - Incorporate dimming issues or develop as separate document
  - Develop driver classifications starting with stand-alone drivers

- Lifetime definition – Industry seems to have settled on a lumen depreciation definition but reliability needs to be incorporated and an industry-accepted complete definition for "life" developed.
  - Define in hours (not years)
  - Include failure criteria (Bx, Lx, confidence levels). For example: B50 (50% catastrophic failure), L70 (Lumen Maintenance to 70%) and F10 (10% max life failure rate)
  - Separate lumen maintenance, catastrophic failures, and define them
  - Discuss and determine minimum "validation" (or seasoning) time (e.g., 1000 hours?)

- Process and facilities for failure mode analysis – The availability of appropriate facilities and evaluation protocols for dissecting failed LED products would be useful for manufacturers and the industry in determining life and failure modes.
  - Identify needed facilities, people, equipment, tests, analysis methods
  - Develop metrics, conditions, methods – a complete consistent method

  - Apply scientific forensic methods and best practices for root cause analysis
  - Identify and qualify labs to perform work
  - Use failure analysis data to understand failure mechanisms as base for accelerated testing and general reliability knowledge
  - Keep data confidential – sanitize

- Accelerated testing – Given that testing needs are long and that extrapolation from limited data is an issue, an accelerated test method should continue to be explored.
  - Break issue into definable and workable pieces (subcomponents, not entire system)
  - Define realistic extreme operational conditions: temperature, humidity, electrical
  - Develop recommendations and how to use them
  - Define typical operational conditions for tests to determine acceleration factors

Additional identified issues surrounding SSL reliability testing include:

- Test method for luminaire lifetime – Because LED performance is critical to its mounting and enclosure (luminaire), a luminaire life test would be useful and should include extrapolation of data, measurement repeatability, and measurement accuracy specifications.
- End-of-life indicator – Industry could use an end-of-life indicator for LEDs so that maintenance and light level issues for LEDs could be related to other technologies.

B. Industry/Market Adaptation

- Serviceability/Replacement – Potential long-term issues with serviceability and replacements that must be dealt with now.

  Replacement Lamps – Currently-available lamps are not fitting into retrofit situations and are not sized as marked (e.g., MR16s can be too fat at the base or too long, PAR 30s can be too short). New ANSI profiles and sockets might need to be created to support SSL on old bases.
  - Raise manufacturer awareness on retrofit incompatibility of replacement lamps.
  - Identify necessary modifications to standards for product geometries (form factors, sockets).
  - Engage trade groups and standards organizations to develop and implement.

  Luminaires – Lack of upgradability and serviceability may hinder SSL market potential. Avoiding single-source solutions and supporting interoperability at a module level (connections, sockets, intelligence) will help minimize repair costs at failure.
  - Identify upgrade paths needed to enable long-term functionality, serviceability, and upgradeability of SSL.
  - Define objectives for interoperability at subcomponent level within SSL products (connections, sockets, controls, power supplies, LED devices…).
  - Engage appropriate trade groups and standards groups to develop or extend standards to support interoperability and interchangeability of subcomponents.

- Education and Information – Consumers and professionals need slightly different information about product life, color characterization, and return on investment for luminaires and lamps.

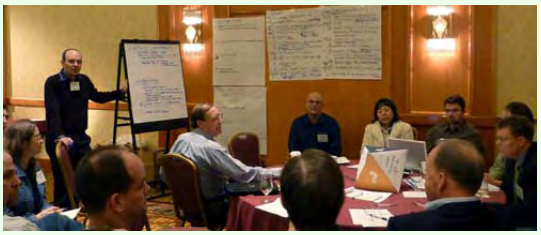
  Consumer education and information needs:
  - Define consistent messages about SSL product life adapted to consumers needs and channels of communication (e.g., for inclusion in product labeling).
  - Develop a strategy for introducing the concept of CQS to consumers and moving from the current use of CRI to CQS.
  - Develop strategies for communicating concepts surrounding SSL return on investment, total life cost, and potential savings for consumers.

Professional education and information needs:

- Develop consistent definitions of SSL product life adapted for professionals, addressing system-level useful life (incorporating both concepts of lumen maintenance and failure rates).
- Develop plan to prepare for and support the publication and adoption of CQS.
- Develop tools and analytic guidelines for estimating return on investment for SSL with an identified, consistent set of potential factors to include.

- Lighting Controls – The introduction of SSL in some lighting applications may create new needs for control protocol standards and lead to new approaches toward defining and fulfilling safety needs.
  - Establish a list of application-specific lighting standards that may be significantly impacted by the advent of SSL lighting and by new approaches made possible by SSL lighting (e.g., RP-8, RP-20…).
  - Identify scopes of study and research that could provide new guidance to existing standards for lighting applications and lighting control (incorporating new concepts in lighting characteristics enabled by SSL technologies).
  - Gather input from a variety of stakeholders regarding control standards that will support interoperability and upgradability and will take advantage of unique characteristics of SSL lighting.
  - Develop a roadmap of potentially needed updates to standards, related research needed to inform these standards updates, and specific standards groups or champions to spearhead efforts in each application area.

C. Qualities of (SSL) Lighting



- Retrofit compatibility (form factor and distribution) – Next steps for achieving high-quality retrofits must go beyond comparable light output and high efficacy to address near-field distribution (shadows, photopic and color uniformity), beam vs. field (light pattern, lack of spill, less uniformity, need for closer spacing resulting in greater total cost and watts). Retrofit compatibility also demands better comparability of color (below).
  - Extend scope of traditional form factors standards to SSL and establish more detailed specifications for package form factor and shape.
  - Define beam pattern requirements for SSL retrofits—define CBCP/Beam angle/Field angle and total lumens (spill, field angle is important, specifying only beam angle is insufficient).
  - Ensure that related standards and criteria are coherent for SSL retrofits (e.g., details of LM-63 IES file format, inclusion of field angle in ENERGY STAR…).
  - Develop a white paper for manufacturers on best practices in retrofit compatibility (include methodology for checking visual beam consistency).

- Color quality and uniformity – Issues include angular color testing methods (uniformity), near field goniophotometry (shadows, angles), binning vs. application (IES), comparability of color quality (CRI), multiple shadow effects, consistency of CCT and CRI (tightness of binning, shift within luminaire life and spatial shift…), and communicating subtleties of color characteristics.
  - Develop a roadmap for color bin tightening; consider market challenges that may arise if different SSL color standards are developed across different countries.
  - Motivate speedy developing and updating of standards and criteria related to color.
  - Develop other methodologies for testing aspects of color quality and uniformity (e.g., possibly adapting IESNA LM-77 photographic method).
  - Investigate possibility of guidance for simple visual test methods for reality checks.

- Flicker – Flicker has potential negative impact for human acceptance, imaging equipment (video cameras/other recording equipment), and high speed tasks. CFL case demonstrates significance of similar issues subject to differences in perception.
  - Support studies and standard development surrounding flicker (working group paper – effects on health/seizures).
  - Clarify definitions/pertinence (flicker index, flicker percentage, other).
  - Gather related background knowledge (such as SAE ARP 1547—aircraft recommended practice/cockpit displays).
  - Incorporate flicker study findings and standards work into related criteria and industry practices (ensure drivers designed in conformity with standards, increase manufacturer awareness, update ENERGY STAR criteria accordingly).

- Modularity/interchangeability – Optimal SSL thermal, optical, and electrical designs are found in applications specifically designed for SSL rather than replacement products for traditional lamps. Encouraging and facilitating interchangeability (modularity) will increase potential for SSL-optimized designs.
  - Encourage standard bases for modules (e.g., upcoming LSD-45 white paper/NEMA).
  - Develop related necessary measurement standards (develop standard for characterizing and testing thermal, electrical and mechanical properties of interface/bases – NEMA ANSI C78-09 working group).
  - Leverage DOE design competitions with specific categories for innovations in modularity (already a key criterion for judging).

- Power quality/power factor – Questions surrounding power quality are increasingly arising (harmonics, performance impacted by line-voltage/switching power supplies, EMC, flicker due to driver design…).
  - Develop relevant driver standard and best practice guidance.
  - Gather industry opinions regarding SSL power quality and related US or international standards.
  - Engage key organizations such as CSA, IEC, NEMA, IEEE, EPRI.

- EMI/ EMC – Electronic and electrical hardware must still work correctly when subjected to certain amounts of EMI and should not emit EMI, which could interfere with other equipment (such as radios) — is this an issue for SSL? These may overlap PQ issues.
  - Determine if there is a need to regulate (low frequencies, high frequencies, EMF…).
  - Determine existing applicable regulatory structures.
  - Identify testing options and applicability to SSL (e.g., measured by EMC labs).
  - Engage key actors/organizations such as FCC, IEEE, IEC (European standards).

- Recyclability/green factor – Long-term acceptance may be impacted by cradle-to-grave costs and environmental impacts. Implications include hazardous materials/MSDSs (material safety data sheets) issues. Industry and local governments may be drivers. Linked to issues of materials compatibility/incompatibility impacting long-term device reliability.
  - Encourage compliance with RoHS, consider REACH.
  - Encourage manufacturer use of recycling symbol on products.
  - Complete and publish cradle-to-grave study.

Additional SSL quality testing issues identified include:

- Glare (BUG reports) IES
- Dimming
- Definition of stated life
- Driver life
- Noise/buzz (fans)
- Consistency/continuity in product identification
- Cost

Next Steps for Key Stakeholder Groups

Each breakout group identified issues, prioritized them and brainstormed possible options for addressing those issues. Specific ideas for actions and paths forward were suggested. To identify actionable solutions, each topic was considered from the perspective of primary stakeholder groups: manufacturers, testing laboratories, trade groups (such as NEMA), DOE efforts (such as CALiPER), and standards efforts.

To facilitate the fulfillment of underlying objectives of the Roundtable meeting, the implications of each topic area are grouped according to the point of view of next steps for each key stakeholder group. Many ideas were considered and discussed during the Roundtable meeting. The list below provides the most significant actionable items suggested for each key stakeholder group.

Action Items for Manufacturers (LED, Luminaires, Other) and Testing Laboratories, LRC, Universities
Key roles — implement best practice and standardized testing procedures, contribute to refining and developing standards and assisting DOE and industry trade organizations

- Materials compatibility/incompatibility information
    - LED device manufacturers provide lists of materials and guidance, include observed reactions and causes.
    - Integrators and fixture manufacturers recognize impact on reliability.
- Characteristics of driver performance and compatibility – define favorable and non-favorable driver characteristics to support standards development, define LED manufacturer tolerances for driver performance, identify different categories (e.g., contains transient protection, is a stand-alone product, is meant for integration, utilizes a photocell, etc.)
- Failure Modes Analysis – contribute voluntary data, best practices, field data.
- Recognize potential for flicker; participate in IEEE flicker work.
- Retrofit compatibility – replacement lamp manufacturers recognize importance and apply strategies to improve compatibility and associated marketing information and labeling. Ensure that screw-based and pin-based products that are marketed using ANSI-defined lamp classes (such as A-19, PAR-38, R-30, MR-16 as defined in ANSI C78.20, C78.21, etc.) meet all form-factor expectations for such lamps. Provide input to NEMA and ANSI regarding SSL-specific needs for updates or clarifications to existing standards. Apply ANSI standards.
- Lighting applications with SSL – study operational and safety implications of SSL under varying conditions (e.g., weather, traffic, human factors), controllability of SSL.
- Increased participation in IES and ANSLG activities
- Address overall life-cycle impact of SSL by ensuring compliance with RoHS, adding appropriate recycling symbols to products and implementing processes to enable recycling of SSL products.

Action Items for Industry Trade Organizations (such as NEMA, UL, CSA, NGLIA, CBEA, REA …)
Key role — provide guidance for SSL manufacturers

- Compatibility/incompatibility of materials – white paper or best practice guide for SSL integrators and replacement lamp and luminaire manufacturers
- Retrofit compatibility –
    - White paper, guidance for manufacturers
    - Standards for screw-based and pin-based lamp form-factors and electrical designations – gather manufacturer input regarding needs for new or updated standards relative to SSL retrofits (work with ANSI standards organization), develop strategies to encourage increased compatibility of SSL retrofits, inform manufacturers about related issues and best practices.
    - Consider short-term and long-term objectives for SSL retrofits and transitional strategies.
- Modularity/interchangeability –
    - Develop standard for characterizing and testing thermal, electrical, and mechanical properties of interface/base (NEMA ANSI C78-09 WG).
    - Publish white paper on sub-assembly interfaces for LED modules in luminaires (NEMA LSD-45).
    - Light engines – follow efforts (e.g., Zhaga Consortium).
- Drivers and controls
    - Publish ANSI/NEMA standard for drivers (SSL1).
    - Publish dimming white paper and work towards dimming standard.
    - Investigate power quality concerns, identify new standards.
    - Investigate flicker, consider best practices regarding flicker and driver design.
- Life cycle – encourage SSL recyclability (web page, best practices), develop LED product sustainability standards.

Action Items for DOE, CALiPER Program and National Laboratories
Key roles — provide unifying leadership, perform studies, educate, and communicate

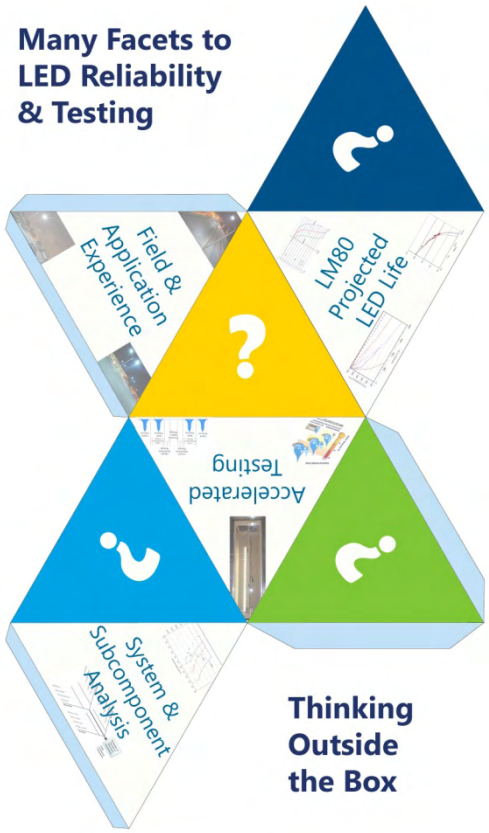
- Reliability and product life –
    - Initiate and lead effort toward FMEA (failure modes and effects analysis) forensics on SSL subcomponents and systems and gather field data.
    - Support working group for definition of lifetime (NGLIA-PQA effort).
    - Accelerated testing baseline for subcomponents, working group for related support and information.
    - Support toward moving needed lifetime and reliability standards forward.
- Power quality and electrical concerns (e.g., EMI, PQ, EMC, surge suppression, flicker)
    - Send letter to NEMA and EPRI requesting opinions on power quality issues and related standards for SSL (such as IEC 61003-2, 61003-3-3, 61003-4-12).
    - Study impacts of PQ on testing methods and reproducibility.
    - Capture and publish SSL flicker data.
- Materials compatibility/incompatibility – provide assistance to NEMA (e.g., look into NASA database on materials incompatibility/compatibility, help with de-identification, possible PQA working group to assemble manufacturer input and best practices guidance).
- Drivers – initiate CALiPER-style testing of SSL drivers.
- Communication and education using DOE conferences, workshops, and online material –
    - Concepts surrounding useful life at system level, TM-21 key points
    - CQS awareness and CQS/CRI comparison demonstration
    - Application-specific guidance and best practices
    - Calculating SSL return on investment.
- Modularity and replaceability – add modularity category specifically to design competitions.
- Support, motivate, and coordinate studies, standards efforts, and related education and communication.

Action Items for Standards Committees (e.g., ANSI, IESNA, CIE, IEEE)
Key roles — develop standard testing methods and technical guidance

- Standardize SSL lifetime definitions (update ANSI/IES RP-16).
- Develop and standardize methodology for measuring luminaire life.
- Develop and standardize methodologies for characterizing and testing LED driver performance, including classifications and dimming.
- Develop standard for interconnect characterization (based from NEMA LSD-45).
- Revise ENERGY STAR (e.g., remove unattainable aspects, add power quality criteria, include field angle requirements for directional replacement lamps).
- Update and publish standards for color of SSL (C78.377 – address binning for outdoor applications, optional tighter specifications for some applications, CIE TC1-69 – CQS).
- Develop other methodologies for assessing color spatial uniformity.
- Review and potentially update application-specific standards to address SSL technology –
    - ANSI/IES RP-8 for roadway lighting
    - ANSI/IES RP-20 for parking facilities
    - Screw-based and pin-based lamp form-factors and electrical designations
    - ANSI standards on communication controls, control protocol standards – data protocols, upgradable firmware
    - Labeling standards.

Conclusions

SSL technology has advanced rapidly in recent years, with improvements in product performance and visible increases in the numbers and varieties of market-available products. Nevertheless, to ultimately meet its significant potential as an energy-saving technology and achieve widespread market penetration, SSL still has a number of hurdles to overcome. To move forward in addressing these challenges, a variety of mechanisms will be needed: research and studies, communication, coordination, consensus development, and standards development. The DOE CALiPER Testing and Standards Roundtable meetings provide a constructive forum for identifying what the industry needs with respect to standards, CALiPER testing, education and information, leadership, and support.



The first DOE SSL Standards and CALiPER Roundtables were focused on solidifying basic SSL testing standards needs and issues. Discussions about long-term testing and reliability were added in 2009. Now, reliability and quality are key concerns and the discussions about how to address these issues are becoming more specific and better defined.

Many 'chicken and egg' type issues have been identified, in particular cases where making progress toward more testing or improved production practices may be contingent on developing testing methodologies and standards. For example, better characterization of driver performance is needed, but first, performance metrics and testing methods must be available. Similarly, in the long term, the most efficient use of SSL technology would be in products specifically designed for SSL devices (as opposed to traditional, socket-based replacement lamps). However, integral SSL luminaires will need to be replaceable or have replaceable components. To support widespread use of designs with replaceable components, the physical, electrical, and thermal characteristics of those components need to be characterized, thus testing methodologies are needed for determining these characteristics.

Identified materials compatibility issues require actions from LED device manufacturers as well as integrators and fixture manufacturers to create lists of materials used and to recognize their impacts on reliability. DOE can provide assistance to NEMA or PQA working groups to assemble this input, understand the interactions, and work towards best practice guidance. This work may also feed into life-cycle issues in terms of recyclability, RoHS compliance, and manufacturer processes to enable recycling.

Long-term reliability issues continue to be discussed. Significant progress has been made in defining and identifying paths forward. Major questions include:

- What components of LED products are critical to their reliability (e.g., lens degradation, driver electronics, heat sink, connections, etc.)?
- What method will emerge for estimating long-term lumen degradation?
- How will all elements of reliability be represented in a combined and coherent manner to users?

More subtle questions of quality were raised – power quality, flicker, color, application-specific issues. For a number of these issues it is important for manufacturers to remember lessons learned from CFLs. Studies and standards work is being done in some of these areas; others were identified as needing to be started.

Essential starting points like these are key to moving forward. The most important standards needs include SSL lifetime definitions and methodologies for measuring luminaire life and characterizing driver performance. Information and education needs include system level life concepts, CQS and CRI comparisons, application-specific guidance and best practices, and calculating SSL ROI. New testing needs identified involve SSL drivers, dimming, power quality, and flicker.

Each stakeholder group has important roles to play to fill the SSL testing and standards gaps. With an enormous expansion in the number of standards efforts under way, there is a clear need for industry experts to get involved in SSL standards committees — particularly from SSL manufacturers at every level of the industry and from all testing laboratories and trade organizations. Photometric testing labs are ideally situated to provide feedback to standards groups, contributing their expertise toward developing solutions. DOE will continue to provide leadership and support cooperation across the various stakeholder groups.

The concerted effort and constructive, engaged enthusiasm of CALiPER Roundtable participants and other SSL industry leaders are paying off as we see rapid progress and growing credibility of SSL testing. While the list of action items for each stakeholder group is still long, it is increasingly well defined and the industry-wide progress is tangible.

Appendix

List of CALiPER Roundtable 2010 Participants

Name	Company
Anderson, Jim	Philips Color Kinetics
Austin, Richard	Gamma Scientific
Berger, Robert	Independent Testing Laboratories, Inc. (ITL)
Bergman, Rolf	CIE USA (International Commission on Illumination)
Billingsley, Craig	ECOS Consulting
Boesenberg, Alex	National Electrical Manufacturers Assocation (NEMA)
Bradley, Dennis	General Electric (GE)
Brodrick, Jim	United States Department of Energy (DOE)
Chesley, Jason	CSA International
Daubach, Ronald	OSRAM SYLVANIA
Elizondo, Phil	Xicato
Gee, Jason	Lighting Lab Inc.
Grather, Michael	Luminaire Testing Laboratory
Han, Yun	Southern California Edison
Hennes, Michael	Illuminating Engineering Society of North America (IES)
Hospodarsky, James	Acuity Brands Lighting, Conyers Lab
Jackson, Andy	Philips Lighting Co.
Kotrebai, Mihaly	GE Consumer & Industrial, Lighting Technology
Lee, Rand	Orb Optronix, Inc.
Leland, Jim	Copia LLC
Lerbs, Kelly	Building Acoustics & Lighting Laboratories, Inc.
Liscio, John	Aurora International Testing Lab
Mellberg, Hans	Bay Area Compliance Laboratories Corp.
Miller, Cameron	National Institute of Standards and Technology (NIST)
Mou, Tongsheng	Zhejiang University, China
Murdoch, Graham	Inst. for Optical Sciences, University of Toronto
O'Boyle, Michael	Lightolier-Philips
Paget, Mia	Pacific Northwest National Laboratory (PNNL)
Petrak, John	EYE Lighting International of North America, Inc.
Radkov, Emil	Illumitex, Inc.
Richman, Eric	Pacific Northwest National Laboratory (PNNL)
Riebling, Michael	Philips
Schutz, Jason	Musco Sports Lighting
Steinberg, Gary	GE Consumer & Industrial Lighting Systems
Steward, Heidi	Pacific Northwest National Laboratory (PNNL)
Swiernik, Jacki	Intertek
Tirpak, Alan	Optronic Laboratories, Inc.
Tunney, Ryder	Lighting Sciences, Inc.
Tuttle, Ralph	Cree Lighting
Wang, Rosa	Sensing Instruments Co., Ltd.
Welsh, Fred	Radcliffe Advisors

CALiPER Roundtable 2010: Agenda

Thursday, February 18, 2010 – Gaithersburg, Maryland

Format: facilitated working sessions, breakouts, identification of paths forward

Note: because the CALiPER Roundtable 2010 follows directly on the heels of the NIST workshops, the Roundtable meeting will focus primarily on SSL testing subjects other than LM-79 and LM-80.

Breakout Group topics: Reliability Testing (life, accelerated…), Industry/Market Adaptation (production processes, new testing approaches/needs…), Qualities of SSL Lighting (glare, flicker, application adaptations, *in situ*…).

7:30 am	Registration/Networking	
8:00 am	Welcome and Introductions Quick Update on Standards Activity/Progress Where CALiPER Is Today, Upcoming Testing Concerns	*Jim Brodrick (DOE)* *Eric Richman (PNNL)* *Mia Paget (PNNL)*
9:00 am	Breakout Groups (Part 1): Broad Topic Areas Breakout format: ~40 minutes, review, broaden, refine issues ~40 minutes, discuss options ~40 minutes, solutions and path forward	*Facilitated* *Groups of 10-15*
11:00 am	Breakout Groups (Part 2): Focused Topic Areas Breakout format: ~40 minutes, review, broaden, refine issues ~40 minutes, discuss options ~40 minutes, solutions and path forward	*Facilitated* *Groups of 10-15*
2:00 pm	Afternoon Regrouping: – 15 minutes summary per breakout topic – Each team provides brief summary of issues, options, paths forward – Short discussion for each topic area	*Group leaders*
4:00 pm	Formulate Action Items – Implications for testing labs – Implications for standards efforts – Implications for manufacturers – Implications for DOE CALiPER	*Facilitated discussion*
5:00 pm	Wrap-up and Adjournment	

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